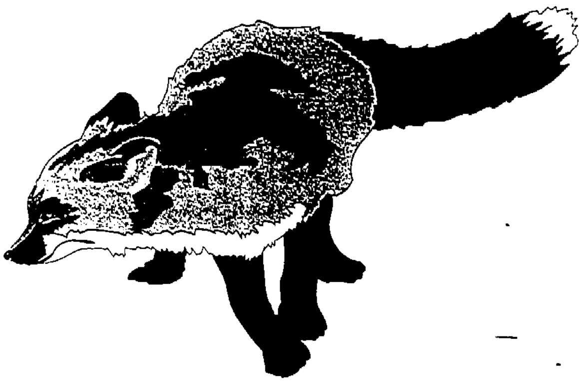
◆ NON-NATIVE WILDLIFE



INTRODUCTION

The large-scale restoration of emergent wetlands, riparian habitat, and adjacent perennial grasslands will be the main focus of a strategy to reduce the adverse impacts of non-native wildlife on the health of the Bay-Delta ecosystem. The goal is a restored Bay-Delta and watershed where the quality, quantity, and structure of the restored habitat discourage colonization by non-native wildlife, provide a competitive advantage to native wildlife, and reduce the vulnerability of native species to nest parasitism and predation from species such as the brown-headed cowbird and starling, and from predation by species such as the red fox and Norway rat.

STRESSOR DESCRIPTION

One of the most serious environmental problems facing California is the explosive invasion of non-native pest plants and animals. Non-native plants, wildlife, fish, and aquatic invertebrates can greatly alter the ecosystem processes, functions, habitats, species diversity, and abundance of native plants, fish, and wildlife.

Many of these invasive species spread rapidly and form dense populations primarily by out-competing native species as a result of large-scale habitat changes that tend to favor non-native species and a lack of natural controls (e.g., natural predators). These non-native species usually have a competitive advantage because of their location in hospitable environments where the normal controls of disease and natural enemies are missing. As populations of non-native species grow, they can disrupt the ecosystem and population dynamics of native species. In some cases, habitat changes have eliminated connectivity of habitats that harbor the native predators that could help to limit populations of harmful non-native species.

The following common but harmful non-native species are found in the Bay-Delta area:

- The red fox was brought to California to be hunted for sport and raised for fur during the late 1800s and early 1900s. The population of this fox appears to be increasing and is now widespread in the Central Valley lowlands and the coastal counties south of Sonoma County. The range of this species also appears to be increasing, and the fox is a threat to many native endangered wildlife species such as the California clapper rail.
- The Norway rat was introduced unintentionally and was established in many areas by the mid-1800s. Increases in urban development, landfills, and riprap areas have resulted in large populations of these rats living along the bay shores. They are a threat to ground-nesting wildlife.
- The feral cat is a major predator to bird and mammal populations in the wetland areas of the Bay-Delta Estuary and wildlife areas elsewhere.
- The bullfrog is not native west of the Rockies but has been successfully introduced throughout most of California from Oregon to Mexico. Bullfrogs can establish and thrive in most permanent aquatic habitats that support emergent vegetation. Population levels in semipermanent aquatic habitats vary from year to year. Bullfrogs feed on most vertebrates and invertebrates that can be seized and swallowed.
- The red-eared slider is a turtle native to the southeastern United States and sold in pet stores throughout the west. The species has become established in the wild in some locations through

releases by pet owners. The range and status of sliders in the Delta are unknown but it is possible that this species is successfully reproducing. If so, it could compete with aquatic species in and dependent on the Delta.

Non-native wildlife species have been sighted throughout the Sacramento and San Joaquin Valleys in a variety of habitats. These include aquatic, riparian scrub, woodland, and forest habitats; valley oak woodland; grassland and agricultural land.

Reestablishing connectivity between habitats would help to reduce non-native species. For instance, restoring the connection between Bay marshlands and upland habitats that have populations of coyotes may help to reduce populations of red fox. Nest conditions in fragmented areas of riparian habitats encourage nest predation and parasitism by non-native species such as starlings and brown-headed cowbirds. Restoring large blocks or broad bands of riparian habitats will eliminate or minimize these adverse effects. Larger blocks may also encourage additional nesting by native deep-forest-nesting species that have been previously excluded.

VISION

The vision for non-native wildlife species is to implement a program to reduce the numbers of harmful non-native wildlife species (i.e., those that threaten the diversity or abundance of native species or the ecological stability of an area).

Reducing the numbers of non-native species and therefore the effects these species have on native wildlife will require a coordinated approach that includes restoring ecosystem processes and functions where applicable and possible, restoring native habitats, reducing or eliminating other stressors that suppress native species, and efforts to control non-native species.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to control non-native species, such as the red fox, are being undertaken on a small scale in the San Francisco Bay area. Most other efforts are associated with damage control in agricultural, urban, and suburban areas in the ERPP study area. Limited efforts have been focused in State and federal wildlife areas that have undertaken control programs on a small scale.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Non-native wildlife either compete with native wildlife species or prey on them. The result is diminished abundance of native species, some of which, such as the California clapper rail, are State or federally listed endangered species. Other than direct control measures, the problems caused by non-native wildlife species can be moderated by habitat restoration programs that reconnect habitats, reduce fragmentation of riparian habitat, and restore connection between lowland and upland habitats.

OBJECTIVES, TARGETS, ACTIONS, AND MEASURES

Two Strategic Objectives address non-native wildlife.

The first Strategic Objective is to reduce the impact of non-native mammals on native birds, mammals, and other organisms.

LONG-TERM OBJECTIVE: Establish mechanisms to minimize the negative effects of house cats, red fox, domestic dogs, roof rats, house mice and other non-native predators and competitors on populations of native birds and mammals, especially at-risk species.

SHORT-TERM OBJECTIVE: Develop both the means and the public support for limiting the invasion and impacts of non-native mammals into natural areas.

RATIONALE: Probably few issues are as potentially contentious to the public as programs to control the numbers of house cats (both tame and feral), red fox (introduced in the Central Valley and spread to marshes throughout the Bay-Delta system), and domestic dogs in natural areas. The fact remains that such predators can have a major impact on the ability of natural areas to support wildlife, including threatened native species such as clapper rails, salt marsh harvest mice, and salt marsh song sparrows. Likewise, non-native rats and mice can impact populations of native rodents and songbirds. Thus there is a major need to educate the public about the tradeoffs in protecting abundant and conspicuous predators that prey on native species, as well as programs to rid areas of other non-native mammals. Economical but lethal means of control (poisons, traps) are often controversial for many of these species and may also affect native species. There is thus a need to focus on prevention (e.g., containment and neutering of pets), on non-lethal means of removal (e.g., live-trapping) where feasible, and on developing support and methods for lethal control where necessary. Prevention and nonlethal methods are typically labor intensive, continuous, and more costly than limited agency budgets can endure. Therefore, there is a need to develop either better methods or bigger budgets for control if self-sustaining populations of many native birds and mammals are to be maintained.

STAGE 1 EXPECTATIONS: An aggressive public information program on the impacts of such non-native mammals in wildlife areas will have been conducted. Plans for long-term control of invasive mammals will have been developed, with alternatives clearly spelling out the impact of no or low control.

> The second Strategic Objective is to limit the spread or, when possible and appropriate, eradicate populations of non-native invasive species through focused management efforts.

LONG-TERM OBJECTIVE: Eliminate, or control to a level of little significance, all undesirable non-native species, where feasible.

SHORT-TERM OBJECTIVE: Eradicate or contain those species for which this can readily be done, gaining thereby the largest benefit for the least economic and environmental cost; and to monitor for the arrival of new invasive species and, where feasible, respond quickly to eradicate them.

RATIONALE: Non-native species are now part of most aquatic, riparian, and terrestrial ecosystems in California. In most instances, control is either not possible or not desirable. However, in some instances, control of invasive species is needed to protect the remaining native elements or to support human uses. Four factors should be considered in focusing control efforts. First, an introduced species is often not recognized as a problem by society until it has become widespread and abundant. At that point, control efforts are likely to be difficult, expensive, and relatively ineffective, while producing substantial environmental side effects or risks, including public health risks. Second, some organisms, by nature or circumstance, are more susceptible to control than others. Third, although biological control is conceptually very appealing, it is rarely successful and always carries some risk of unexpected side effects, such as an introduced control agent "controlling" desirable native species. And fourth, physical or chemical control methods used in maintenance control rather than eradication require an indefinite commitment to ongoing environmental disturbance, expense, and possibly public health risks. Overall, the most efficient, cost-effective, and environmentally beneficial control programs may be those that target the most susceptible species, and species that are not yet widespread and abundant.

STAGE 1 EXPECTATIONS: An assessment will be completed of existing introductions to identify those with the greatest potential for containment or eradication, and consider this in prioritizing control efforts. A program will have been implemented to monitor for, and respond quickly to contain and eradicate new invasions, where this is possible. A mechanism whereby new invasions can be dealt with quickly and effectively will have been developed an implemented.

RESTORATION ACTIONS

The general target for non-native wildlife is develop and implement control programs to reduce population abundance and to reestablish larger blocks of connected habitats to provide more extensive habitat and protection for native wildlife.

The Ecosystem Restoration Program Plan (ERPP) supports the following activities that would reduce adverse effects of non-native wildlife on native species:

- Reduce red fox populations in and adjacent to habitat areas suitable for California clapper rail, California black rail, salt marsh harvest mouse, and San Joaquin kit fox to reduce predation on eggs, juveniles, and adults and assist in the recovery of these native species.

- Reduce Norway rat populations in and adjacent to suitable habitat areas for California clapper rail, California black rail, and salt marsh harvest mouse to reduce predation on eggs, juveniles, and adults and assist in the recovery of these species. A combination of activities would be required to prevent the rats from establishing in important habitat areas (e.g., remove garbage and rubbish; ensure proper construction of residences and food storage structures; break down stubble in field crops, such as corn, to expose the rodents to predation during winter) and reduce populations in important habitat areas where the rats are already established (e.g., use biological controls, practice the environmental controls listed above, and use rodenticides).
- Reduce feral cat populations in and adjacent to suitable habitat for California clapper rail, California black rail, salt marsh harvest mouse, San Joaquin pocket mouse, kangaroo rat, and blunt-nosed leopard lizard habitats to reduce predation on eggs, juveniles, and adults and assist in the recovery of these species.
- Periodically drain aquatic habitats inhabited by bullfrogs to reduce the populations of these species (bullfrog larvae have an extended growing season, sometimes even overwintering, compared to native amphibians such as the California red-legged frog).
- Investigate the feasibility of increasing the harvest of bullfrogs without disturbing native species.
- Implement a "buy-back" or "take-back" program in pet stores to reduce the number of red-eared sliders released into the Delta.

MSCS Conservation Measures

The following conservation measures were included in the Multi-Species Conservation Strategy (2000) to provide additional detail to ERP actions that would help achieve species habitat or population targets.

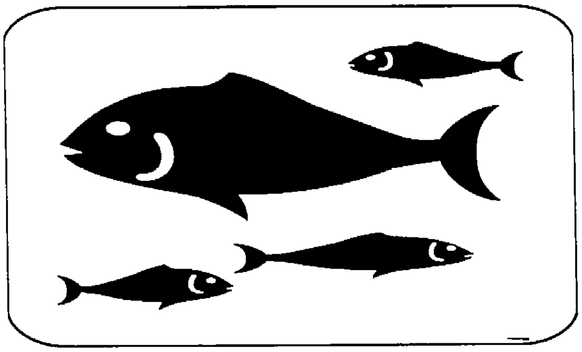
- To the extent practicable, control non-native predator populations in occupied habitat areas and salt marshes restored under the ERP.
- To the extent practicable, restore riparian habitats in patch sizes sufficient to discourage nest parasitism by brown-headed cowbirds.

References

Multi-Species Conservation Strategy. 2000. CALFED Bay-Delta Program, Programmatic EIS/EIR Technical Appendix. July 2000.

Strategic Plan for Ecosystem Restoration. 2000. CALFED Bay-Delta Program, Programmatic EIS/EIR Technical Appendix. July 2000.

◆ PREDATION AND COMPETITION



INTRODUCTION

Predation and competition are natural ecological functions; however, unnatural levels of each can result in adverse effects to important sport and commercial fisheries and species of concern such as winter-run chinook salmon. For example, the potential adverse effects of competition between native and hatchery-reared salmonid stocks for food and other resources are a concern. Predation on important fish species and stocks is known to be a problem in the Central Valley, however, at specific sites or under specific environmental conditions.

Efforts to control the extent of unwanted predation and competition, particularly the loss of species of concern, are an important component in restoring health to the Bay-Delta system and in providing for other beneficial uses of water.

STRESSOR DESCRIPTION

CHINOOK SALMON AS A PREY SPECIES

Predation occurs throughout the river and ocean life-history stages of chinook salmon, but the magnitude and extent of predation have not been quantified. There are essentially three classes of predators on chinook salmon: birds, fishes, and marine mammals. Predatory birds include diving birds such as cormorants and gulls; terns and mergansers; wading birds such as snowy egret, great blue heron, black-crowned night heron, and green heron; and raptors such as osprey.

Predatory fish include both native and non-native species. Native predatory species include Sacramento squawfish, prickly sculpin, and steelhead. Non-native predatory species include striped bass, white catfish, channel catfish, American shad, black crappie, largemouth black bass, and bluegill.

Predation by native species is a natural phenomenon and should not have a serious effect on naturally produced chinook salmon in areas where shaded riverine aquatic (SRA) habitat and other types of escape cover are present. Chinook salmon has co-evolved with its native predators and has developed life-history strategies to avoid predation. However, predation by non-native species and increased predation resulting from artificial in-water structures and loss of instream habitat diversity may have resulted in gross imbalances in the predator-prey relationships and community structure in which chinook salmon evolved.

Artificial structures, such as dams, bridges, and diversions, create shadows and turbulence that tend to attract predator species and create an unnatural advantage for predators (Stevens 1961, Vogel et al. 1988, Decoto 1978). Specific locations where predation is of concern include Red Bluff Diversion Dam (RBDD), Glenn-Colusa Irrigation District's (GCID's) Hamilton City Pumping Plant, flood bypasses, release sites for salmon salvaged at the State and federal fish facilities, areas where rock revetment has replaced natural river bank vegetation, the Suisun Marsh Salinity Control Gates, and Clifton Court Forebay (CCF).

Predation at RBDD on juvenile chinook salmon is believed to be higher than natural levels because of the water quality and flow dynamics associated with the operation of this structure. The most important predator at RBDD is squawfish (Garcia 1989). Squawfish migrate annually upstream to RBDD from March to June, but some squawfish are present year round at the dam. Striped bass have also been captured immediately below RBDD in limited but regular numbers and have been found to have fed on juvenile salmonids (U.S. Fish and Wildlife Service unpublished data cited in Garcia 1989, Villa 1979). Striped bass were also observed by U.S. Fish and Wildlife Service (USFWS) divers below RBDD in September 1982, and five American shad captured at RBDD in June 1976 contained two to seven juvenile salmon each (Hall 1977).

Some chinook, such as juvenile winter-run chinook salmon that migrate downstream soon after emerging from the gravel in summer and early fall, will encounter RBDD when the gates are still down. They must cross Lake Red Bluff when turbidity is generally low and water temperatures are still relatively high. Because of their small size, these early emigrating winter-run juveniles may be very susceptible to predation in the lake by squawfish and cormorants (Vogel et al. 1988). In passing the dam, juveniles are subject to conditions that greatly disorient them, causing them to be highly susceptible to predation by fish or birds.

Prior to reoperation, late-migrating juvenile chinook salmon that passed RBDD in early spring most likely suffered the greatest losses because squawfish abundance was higher at that time of year and river conditions were generally favorable for predators, especially during dry years. Recent operation have reduced the aggregation of squawfish and reduced losses during the period in which the gates are up. The impacts of these losses are also more important because of the overall higher survival of these smolts (versus actively migrating fry) and their greater probability of contribution to the adult population.

There are some concerns that predation is higher in flood bypasses. In one survey of the Sutter Bypass, the most abundant species captured included chinook salmon and Sacramento squawfish (Jones & Stokes Associates 1993a).

GLENN-COLUSA IRRIGATION DISTRICT HAMILTON CITY PUMPING PLANT

Evaluations at GCID Hamilton City Pumping Plant suggested that predation could be an important factor contributing to losses of juvenile salmonids at that location (Decoto 1978). In mark-recapture studies, 66% of the salmon were unaccounted for in bypass evaluations, and 82% were unaccounted for in culvert evaluations. More recent studies suggest that Sacramento squawfish is the primary predator at the pumping plant (Cramer 1992), although striped bass were also found with young chinook salmon in their stomachs.

FISH SALVAGE RELEASE SITES

Orsi (1967) evaluated predation at the Jersey Island release site for salvaged fish from the State and federal fish facilities from mid-June through July in 1966 and 1967. Striped bass was the major predator at the release site, with black crappie and white catfish ranking second and third, respectively. Orsi estimated that overall predation occurred on about 10% of the salvaged fish released per day during multiple releases (one million fish/day), and more than 80% of the predation was from striped bass. He qualified this estimate as potentially being high and not applicable to other sites such as the Sacramento River. Similarly, Pickard et al. (1982) conducted predation studies of salvage release sites from 1976 to 1978. Fish, salvaged from the State's fish facility, were regularly transported and released into the lower Sacramento River at Horseshoe Bend. More predator fish were collected at the release site than at the control site, with striped bass and Sacramento squawfish being the primary predators. Also, more fish remains were found in the predators' stomachs at the release site than at the control site.

ROCK REVETMENT SITES

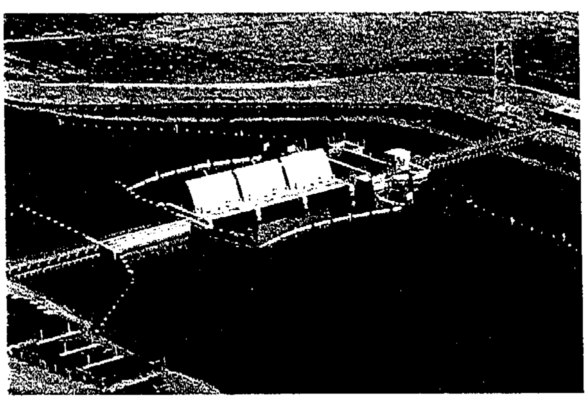
USFWS conducted a study to assess the relationship of juvenile chinook salmon to the rock revetment type bank protection between Chico Landing and Red Bluff (Michny and Hampton 1984). They found that predatory fish, such as Sacramento squawfish and prickly sculpin, were more abundant at riprapped sites than at naturally eroding bank sites with riparian vegetation. Conversely, juvenile salmon were found more frequently in areas adjacent to riparian habitats than at riprapped sites. Riparian habitats provide overhead and submerged cover, an important refuge for juvenile chinook from predators.

CLIFTON COURT FOREBAY

Overall predation rates for salmon smolts in CCF have been estimated at 63-98% for fall-run chinook (California Department of Fish and Game 1993a), and 77-99% for late-fall-run chinook (Table 4). In mark-recapture studies, estimated mortality rate per mile in CCF was 91.3%, compared with 2.7% for the central Delta and 0.9% for the mainstem Sacramento River (between Ryde and Chipps Island). This difference was thought to result from the greater abundance of predators, primarily striped bass, in CCF, as well as hydraulic actions and the operational and physical design of CCF. During high tide, striped bass density in CCF has been estimated to be three to 17.5 times higher than the density of striped bass in the Delta. At low tide, striped bass density in CCF has been estimated as roughly five to 21 times higher than in the Delta.

SUISUN MARSH SALINITY CONTROL STRUCTURE

The California Department of Fish and Game (DFG) conducted predation studies from 1987 to 1993 at the Suisun Marsh salinity control structure to determine if the structure attracts and concentrates predators. The dominant predator species at the structure was striped bass, and juvenile chinook were identified in their stomach contents. Catch-per-unit-effort (CPUE) of bass has generally increased at the structure from 1987 (less than 0.5, preproject) to 1992 (3.0, postproject), and declined somewhat in 1993 (1.5) (California Department of Fish and Game 1994c). In comparison, CPUE was 3.44 at CCF and 1.65 at the south Delta barriers during the same period, using identical gear.



OCEAN PREDATION

Ocean predation very likely contributes to natural mortality in naturally and hatchery-produced chinook salmon stocks; however, the level of predation is unknown. In general, chinook salmon are prey for pelagic fishes, birds, and marine mammals including harbor seals, sea lions, and killer whales. There have been recent concerns that rebounding seal and sea lion populations, following their protection under the Marine Mammal Protection Act of 1972, have resulted in substantial mortality for salmonids.

Ocean predation rates on Central Valley chinook salmon have not been evaluated, but several studies have been conducted in other estuaries. At the mouth of the Russian River, Hanson (1993) found that maximum population counts of seals and sea lions corresponded with peak periods of salmonid returns to the hatchery upriver.

However, Hanson concluded that predation was minimal on adult salmonids because only a few pinnipeds foraged in the area, their foraging behavior was confined to a short portion of the salmonid migration, and their capture rates were low.

In the lower Klamath River, Hart (1987) reported predation rates of about 4% and 8% in 1981 and 1982, respectively, from harbor seals on chinook, coho and steelhead. It is important to note that marine mammal and chinook salmon populations evolved together and coexisted long before humans played a role in controlling either species.

GENERAL ANALYSIS OF STRIPED BASS PREDATION ON CHINOOK SALMON

Food habit studies conducted by numerous investigators indicate that chinook salmon are not an important component in the diet of striped bass, although, at times, young salmon, primarily fall-run, have constituted a substantial part. Generally, this has occurred in the Sacramento River upstream of the estuary and has been localized at water management structures, bridge abutments, and other predator habitats. It also occurs at structures that cause disorientation of juveniles such as RBDD. In the Delta, it is a known problem in CCF and at sites where large numbers of artificially produced chinook salmon are released.

The studies reveal that, except at localized sites and structures, striped bass are less likely to eat salmon in Suisun Bay and the Delta than in the rivers above the Delta. The greater vulnerability of salmon in the river may be a result of the greater clarity and the smaller width of the river. In many areas, bank protection activities, such as maintaining levees and riprapping, have removed SRA habitat and eliminated escape cover needed by young fish.

Summary of Clifton Court Forebay Prescreen Loss Studies
on Hatchery Juvenile Chinook Salmon

Date	Salmon Run	Prescreen Loss Rate (%)	Temperature (avg/day°F)	Pump Exports (avg. af/day)	Predator Abundance	Size at Entrainment (mm fl)
Oct 76	Fall	97.0	65.4	2,180	NA	114
Oct 78	Late-fall	87.7	57.5	4,351	NA	87
Apr 84	Fall	63.3	61.2	7,433	35,390	79
Apr 85	Fall	74.6	64.1	6,367	NA	44
Jun 92	Fall	98.7	71.7	4,760	162,281	77
Dec 92	Late-fall	77.2	45.4	8,146	156,667	121
Apr 93	Fall	94.0	62.0	6,368	223,808	66
Nov 93	Late-fall	99.2	53.7	7,917	NA	117

NA = estimates not available

Source: California Department of Fish and Game 1993.

Opportunities to Reduce Predation

There have been only limited efforts to reduce predation problems. At RBDD, a squawfish derby was held in 1995 to reduce squawfish abundance. However, this sport fishery is unlikely to measurably alleviate predation from a native migratory species. The fishery could temporarily reduce squawfish abundance, but more squawfish are likely to repopulate the area. Sacramento squawfish are also more abundant at RBDD during spring, and a spring fishery could cause incidental catches of winter-run chinook.

The preferred solution to reduce predation at RBDD is to eliminate or reduce the feeding habitat that RBDD creates by seasonally or permanently raising the gates. It is anticipated that the GCID Hamilton City Pumping Plant will be redesigned and relocated on the main channel of the Sacramento River, upstream of its present location on an oxbow. The new design will eliminate predator habitats and should substantially reduce the existing level of predation and other problems caused by stream channel and gradient changes in the Sacramento River in recent years.

Predation problems occurring in CCF may be resolved by alternative conveyance facilities that reduce the quantity of water drawn directly into the forebay from the Delta.

Another important opportunity to reduce predation on target fish species is by recreating or restoring a more complex mosaic of instream habitats. These habitats can contribute to reduced predation and competition by allowing species to partition themselves among a more diverse array of available habitats.

Predation and Competition with Hatchery-Reared Fish

The extent of predation by hatchery salmonids on naturally produced chinook salmon and steelhead is also not known. Steelhead releases, primarily by the Coleman National Fish Hatchery, may have the greatest potential for inducing unnatural levels of predation on naturally produced chinook salmon. Coleman National Fish Hatchery has a capacity to raise about one million yearling steelhead. Present production targets a release of about 600,000 in January and February at 125-275 millimeters (mm) long (four fish/pound). Predation on hatchery-produced steelhead is thought to be further reduced because these steelhead tend to outmigrate rapidly and during a period when inriver foraging conditions are suboptimal (i.e., high turbidity, low water temperature).

Predation by residualized hatchery-released steelhead, however, could be substantial. The extent of residualization of released steelhead trout smolts is unknown. With a potential annual release of more than one million steelhead trout at Coleman National Fish Hatchery, even a small rate of residualization could result in a substantial predator population.

Predation from steelhead released by Feather River Hatchery and Nimbus Fish Hatchery has not been evaluated but may also be important. Each of these hatcheries has a capacity to raise about 400,000 yearling steelhead to a size of 3-4 fish/pound. Feather River Hatchery fish are planted in the Feather River below Yuba City, most by the end of March, and the Nimbus Fish Hatchery fish are mainly trucked and released in the Carquinez Strait between January and April (California Department of Fish and Game 1990). Feather River hatchery steelhead are released at a large enough size and at a time when they could intercept winter-run chinook. Nimbus Hatchery steelhead would also be large enough to prey on winter-run chinook salmon.

Chinook salmon and steelhead artificially produced at and released from hatcheries may compete with (or displace) their naturally produced counterparts for food or habitat in the river, estuary, and open ocean. The major source of competition from hatchery salmonids in the upper Sacramento River would be from releases from the Coleman National Fish Hatchery on Battle Creek. The extent of competition between naturally produced chinook and releases from other hatcheries is of particular concern. The extent of this competition is unknown but is believed to be low. The size differences between the various chinook salmon stocks may also result in segregation according to size-dependent habitat preferences because juvenile chinook salmon and steelhead move to faster and deeper waters as they grow and do not compete with fry (Everest and Chapman 1972).

Competition between hatchery runs and naturally produced salmon in the ocean is most likely limited in most years. The ocean environment has been assumed to be nonlimiting because, historically, the abundance of wild salmon was much higher than the combined abundances of wild and hatchery salmon at present (Chapman 1986, Bledsoe et al. 1989), and standing stocks and production rates of prey resources were estimated to far exceed the food requirements of the present ocean populations (LaBrasseur 1972, Sanger 1972). A number of studies have found evidence that ocean conditions may limit salmon production and a substantial percentage of the total natural mortality may occur during early marine life (Parker 1968, Mathews and Buckley 1976, Bax 1983, Furnell and Brett 1986, Fisher and Pearcy 1988). However, in many populations, much of this mortality appears to occur in the first month at sea regardless of the number of smolts released. Brodeur et al. (1992) suggested that local depletion of resources could occur, especially of fish prey in a warm year of reduced productivity (e.g., in 1983) when prey were smaller and competitors, such as mackerel, were abundant. But, in general, juvenile salmon do not appear to be food-limited in coastal waters during most normal years (Brodeur et al. 1992, Peterson et al. 1982, Walters et al. 1978).

VISION

The vision for predation and competition is to reduce unnatural levels to restore fish populations by removing, redesigning, or reoperating inwater structures, diversion dams, and hatchery practices.

The ERPP vision for unnatural levels of predation and competition is closely linked to physical habitat restoration objectives and targets in the visions for the Sacramento River Ecological Management Zone, the Sacramento-San Joaquin Delta Ecological Management Zone, the San Joaquin River Ecological Management Zone, and the Suisun Marsh/North San Francisco Bay Ecological Management Zone. In addition, the visions for chinook salmon, steelhead trout, striped bass, and artificial production contain strategies to ameliorate the adverse effects of competition and predation. Cumulatively, these visions present a robust integration of implementation objectives, restoration targets and actions that will contribute substantially to the restoration and maintenance of a healthy ecosystem, and healthy populations of valuable sport and commercial fisheries.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Three major programs to restore chinook salmon and steelhead populations exist within the Central Valley.

The Secretary of the Interior is required by the Central Valley Project Improvement Act (Public Law 102-575) to double the natural production of Central Valley anadromous fish stocks by 2002. The National Marine Fisheries Service is required under the Endangered Species Act to develop and implement a recovery plan for the endangered winter-run chinook salmon and to restore the stock to levels that will allow its removal from the list of endangered species. DFG is required under State legislation (The Salmon, Steelhead Trout and Anadromous Fisheries Program Act of 1988) to double the numbers of salmon and steelhead trout that were present in the Central Valley in 1988.

These programs, together with the ecosystem approach provided in ERPP, will cumulatively provide for substantial improvements in the health of fish populations, their habitats, and the ecosystem processes that create and maintain habitat and lessen the adverse effects of stressors.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

The solutions to reducing unnatural levels of predation and competition are linked to improved hatchery management strategies which include reevaluation of release programs for hatchery produced fish. The solution also include modification to structures that promote predation such as predator habitat provided by instream structures. Some structures, such as RBDD, increase the vulnerability of young fish to predation. The restoration of riparian and riverine aquatic habitats, set back levees, and increases in the area and quality of shallow water habitat throughout the Delta and Suisun Bay will also provide important ecological components to lessen species interactions and the potential for predation.

OBJECTIVE, TARGETS, ACTIONS, AND MEASURES

The Strategic Objective for predation and competition is to ensure that chinook salmon, steelhead, trout, and striped bass hatchery, rearing, and planting programs do not have detrimental effects on wild populations of native species and ERP actions.

LONG-TERM OBJECTIVE: To rehabilitate man-made structures in the ecosystem to reduce predation losses associated with those structures to levels that will aid in the recovery and restoration of all species. Reduce competition between naturally spawned and hatchery reared species, by establishing hatchery protocols that benefit naturally spawned populations.

SHORT-TERM OBJECTIVE: Reduce the effects of predation associated with operations by better managing the State federal, and private infrastructures associated with aquatic environments. Modify physical characteristics of these facilities to detract from predator use. Study the effects of hatchery reared population have on naturally spawned populations within the ERPP study area.

RATIONALE: Predation related mortality associated with the operation of State, federal, and private facilities within the Sacramento-San Joaquin Estuary and its watershed contributes to the decline of resident and outmigrant aquatic species. Elevated predator levels in and near these man-made structures (screening facilities, diversions, and Clifton Court Forebay) and operational events (temperature plumes from power plants,) have been well documented. These structures have created an environment that is beneficial to predators. Within Clifton Court Forebay (CCF) predators have been documented orienting themselves with the radial gates when they are open, possibly feeding on hapless prey as they are drawn into the forebay (Bolster, 1986). In addition, striped bass have been noted at the trash racks, in front of the primary screens, feeding on marked fish as they are introduced into the water during a marked recapture experiment (DFG unpublished data). In studies done near the outfall of the cooling tower return and resulting thermal plume, predator populations have been demonstrated to increase as compared to other non-thermally elevated areas. Controlling these predators and developing more efficient methods to limit the exposure of prey species to these facilities will assist in the recovery of both listed and non-listed species.

Considerable discussion exists as to the effect of hatchery reared fish on non-hatchery reared fish. This information is not well documented and future efforts will reguire additional information to clarify the issue.

STAGE 1 EXPECTATION: Projects will be undertaken that identify and reduce predation